CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-162

Faults in the Volcanic Tableland, Mono and Inyo Counties

by

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INTRODUCTION

Potentially active faults located in southern Mono and northern Inyo Counties evaluated in this FER comprise a complex, extremely wide zone of unnamed faults in the Volcanic Tableland north of the city of Bishop (figure 1). The Volcanic Tableland study area is located in parts of the Bishop, Casa Diablo Mountains, Mount Tom, and White Mountain Peak 15-minute quadrangles. These faults are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active and well defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act (Hart, 1980).

This fault evaluation consists of a literature review and reconnaissance air photo interpretation. Time limitations precluded a thorough study of the area with respect to both detailed air photo interpretation and field observations. The Volcanic Tableland study area is limited to those quadrangles in which previous fault evaluations were completed. Zoning was recommended for segments of the Sierra Nevada and White Mountains frontal faults and the Fish Slough fault (see Bryant, 1984a, 1984b). Additional Quaternary faults related to extensional tectonics in the Volcanic Tableland extend in a complex manner northward to Benton, and possibly as far as the Mono Lake area (figure 1).

SUMMARY OF AVAILABLE DATA

The Volcanic Tableland study area is characterized by Basin and Range-style extensional faulting. Faults in the Volcanic Tableland generally trend north to northwest and form an exceptionally complex and distributive zone of deformation. Topography in the study area is generally subdued in the southern part of the study area, becoming more rugged in the northwestern part of the study area. Development in the study area is almost nonexistent, and the area is currently under no developmental pressure.

Rocks in the Volcanic Tableland study area consist almost exclusively of Pleistocene Bishop tuff (700,000 yrs. old) (Bateman, 1965; Crowder and Sheridan, 1972; Rinehart and Ross, 1967; Bailey and Koeppen, 1977). Surficial deposits include late Pleistocene terrace deposits, Holocene alluvial deposits in the Owens River floodplain and Fish Slough, and thin veneers of late Pleistocene (?) alluvium deposited in tectonic basins and ephemeral stream channels in the Volcanic Tableland (Bateman, 1965; Crowder and Sheridan, 1972).

Bateman (1965) observed that internal layering in the Bishop tuff is parallel to the surface of the Volcanic Tableland, especially in the south-central and southeastern regions where resistant, partly welded to welded tuff outcrops at the surface. This indicates that relatively little erosion has occurred in this area of the Volcanic Tableland since deposition of the Bishop tuff. In contrast, the western and northeastern parts of the Volcanic Tableland have undergone a significant amount of erosion, and the number of identifiable faults is noticeably less (Bateman, 1965; Crowder and Sheridan, 1972; figure 2). The relatively pristine and resistant surface of the south-central and southeastern parts of the Volcanic Tableland in the Bishop quadrangle provides a unique reference plane that has probably preserved all structural deformation since deposition of Bishop tuff.

Bateman mapped an extremely complex zone of normal faults in the Volcanic Tableland north and northwest of Bishop (figure 2). Faults are characterized by both east- and west-facing scarps along a general north to northwest trend. At first glance, the sheer number of faults is almost overwhelming, but upon careful examination, a distinctive, left-stepping pattern is apparent. Broad, southeast-plunging folds are associated with the normal faulting. Bateman postulated that a right-lateral rotational couple, in addition to the general east-west extension occurring in the region (Sheridan, 1975), best explains deformation in the Volcanic Tableland.

The Owens River trends east-west along the southern extent of the Volcanic Tableland and remnants of three terrace levels were mapped by Bateman (figure 2). Bateman postulated that these terraces are equivalent in age to dissected alluvial fans along the eastern slope of the Sierra Nevada south of Bishop. Bateman assumed the lowest and youngest terrace is latest Pleistocene to Holocene in age. Bateman mapped a complex zone of shears in these terrace deposits, based mostly on air photo interpretation (Bateman, 1965, pl. 7; figure 2, this report). The pattern of faulting in the terrace deposits is similar to the pattern of faulting in the Volcanic Tableland, strongly indicating that the tectonic deformation that occurred after deposition of the Bishop tuff has continued through late Pleistocene and probably into Holocene time. Bateman noted that the general absence of large scarps on these terrace surfaces indicated that the majority of deformation in the Tableland occurred prior to cutting of the terraces. However, the scarps are generally higher on the older terraces and fans, indicating that faulting has occurred progressively throughout latest Pleistocene time.

A northeast-trending fault in the southwestern part of the Volcanic Tableland reportedly offsets Holocene alluvium in Sec. 24 at the Owens River Gorge (Bateman, 1965; figure 2). Bateman (1965, pl. 7) postulated that this fault projects southwest along the west side of the Tungsten Hills. He did not map Holocene alluvium to be offset along this southwest projection, but a contact between two Holocene alluvial deposits mapped by Bateman (Sec. 26, T6S, R31E) coincides with and parallels the southwest projection of this fault (figure 2).

Crowder and Sheridan (1972) mapped a significantly less complex zone of faults in the SW 1/4 of the White Mountain Peak quadrangle (figure 2). The reduction in the number of faults in this part of the Tableland is probably due to increased rates of erosion of the less well-indurated units of Bishop tuff (Crowder and Sheridan, 1972). Crowder and Sheridan mapped west-facing scarps in Holocene alluvium in Sections 7, 17, 28, and 30, T4S, R32E (figure 2). In addition, numerous faults juxtapose Holocene alluvium against Bishop tuff (figure 2). It is not clear if the alluvium is faulted, or has been deposited in the tectonic depressions that are very common on the Tableland surface.

Rinehart and Ross (1957) mapped a broad, northwest-trending zone of normal faults in the SW 1/4 of the Casa Diablo Mountain quadrangle (figure 2). Bishop tuff is offset and, locally, Holocene alluvium is juxtaposed against Bishop tuff (figure 2). (They also mapped several faults in similar material in the SE 1/4 of the Casa Diablo Mountain quadrangle, but this area is not evaluated in this study). Bailey and Koeppen (1977) generally used the mapping of Rinehart and Ross. However, Bailey and Koeppen mapped a complex, northwest-trending zone of faults just east of Lake Crowley that differs significantly from the mapping of Rinehart and Ross (figure 2). Pleistocene lake deposits are offset, but Holocene deposits were not mapped in the Volcanic Tableland study area. However, north of the Volcanic Tableland study area (just north of Watterson Canyon) Holocene alluvium locally is offset by faults associated with this northwest-trending zone (figure 2).

INTERPRETATION OF AERIAL PHOTOGRAPHS

Air photo interpretation by this writer of faults in the Volcanic Tableland study area was accomplished using U.S. Bureau of Land Management air photos (CA01-77, 1977, 1:24,000 scale) and U.S. Forest Service airphotos (IN04, 1972, 1:15,840 scale). Field observations were not made due to time limitations.

Interpretation of air photos by this writer was intended only to verify the location and degree of definition of faults mapped by others, rather than to complete a detailed independent interpretation. The location of the vast number of faults mapped by Bateman (1965) was generally verified by this writer (figure 2). However, not all faults were mapped by Bateman, and an extremely complex zone of faults exists in the south-central part of the Volcanic Tableland (figure 3). Faults mapped by Crowder and Sheridan (1972) generally are not as well defined in the SW 1/4 of the White Mountain Peak quadrangle (figure 2). Locally, their fault traces were either not verified by this writer, or were mislocated as much as 500 feet (figure 2).

Numerous tonal lineaments and low scarps forming a pattern similar to faults in the Tableland were observed in the terrace surfaces just south of the Owens River. Well-defined scarps in the youngest terrace deposits indicate latest Pleistocene to Holocene offset in Sections 23 to 26, 35, and 36, T6S, R32E and were recommended for zoning in FER-153 (Bryant, 1984a). Additional evidence of possible Holocene faulting was observed in Sec. 26, T6S, R31E and Sections 17 and 28, T4S, R32E (figure 2).

The majority of the Volcanic Tableland study area is problematical with respect to evaluation of recency of faulting due to the general lack of late Pleistocene and Holocene deposits. In addition, abundant fault scarps within resistant units of Bishop tuff have been preserved in almost pristine condition. Late Pleistocene and possible Holocene offset is indicated in areas peripheral to the Volcanic Tableland and is clearly associated with tectonic processes affecting the Volcanic Tableland. Thus, it becomes necessary to differentiate those recently active faults in the Volcanic Tableland from earlier Pleistocene faults. It was initially thought that the steepness of scarp-slopes and sharpness of scarp crests, in relation to scarp height, might be a factor that would help differentiate ages of offset in similar material. However, a great variety of scarp-slope angles, sharpness of crests, and heights was observed. Differentiating scarps based on height also was not useful. Sharp, steep scarp-slopes were observed on relatively small scarps ($\geq$ 5 feet) and relatively rounded scarps of 50 feet or greater were observed by this writer with a full range of intermediate values (figure 2).

An east-southeast-trending abandoned stream channel is offset by faults near the south end of the Volcanic Tableland (figure 2). Some segments of the stream channel contain alluvium that may have been deposited prior to offset of the channel. Photographic tonal qualities of the alluvium are similar to alluvium deposited in tectonic basins in the Tableland and a late Pleistocene to Holocene age is implied. However, it is not clear whether the alluvium in the stream channel accumulated by stream deposition, or by post-channel offset deposition similar to the accumulation of alluvium currently taking place in tectonic depressions adjacent to fault scarps. Other drainage systems also are disrupted by faulting in the eastern part of the study area.

Faults in the SW 1/4 of the Casa Diablo Mountain 15-minute quadrangle generally are not as well defined as faults in other parts of the Volcanic Tableland study area (figure 2). Faults are relatively minor, and those faults characterized by larger scarps have usually been eroded. No direct geomorphic evidence of Holocene faulting was observed by this writer in this part of the study area. Faults mapped by Bailey and Koeppen in the northern part of the SW 1/4 Casa Diablo Mountain quadrangle are characterized by minor scarps in lake terrace gravel deposits Bailey and Koeppen consider to be middle Pleistocene in age. Well-defined tonal lineaments in Holocene alluvial fans in the Watterson Canyon area (just north of this study area) coincide with faults mapped by Bailey and Koeppen, but scarps in Holocene alluvium were not observed by this writer (figure 2).

SEISMICITY

The region in which the Volcanic Tableland study area is located has a relatively high level of seismicity (figure 4). A scattering of epicenters in the M = 3.0 to 4.9 range occur in the Volcanic Tableland. The cluster of epicenters in the western part of the Tableland is probably associated with the Round Valley fault zone, a major range front fault. The quality of epicenter locations and the paucity of the seismic network during this timeframe preclude the matching of specific seismic events with specific fault segments.

CONCLUSIONS

Geomorphic evidence suggesting relatively minor Holocene faulting was observed by this writer in latest Pleistocene to Holocene terrace deposits and Holocene floodplain deposits just south of the Volcanic Tableland, in the southwest part of the Tableland (Sec. 26 and 24, T6S, R31E), and in the northern part of the Tableland (Sec. 17 and 28, T4S, R32E) (figure 2). Almost all of the faults mapped by Bateman (1965), Crowder and Sheridan (1972), and Bailey and Koeppen (1977) were verified by this writer, based on air photo interpretation. A small area mapped by this writer (figure 3) indicates that additional faults can be mapped in the Volcanic Tableland, and many additional tonal lineaments probably related to tectonic deformation exist that were not mapped by this writer or other workers.

It is probable that Holocene faulting occurs in the Volcanic Tableland, but along which faults? Where erosion has occurred in the Tableland, the density of observed faults is much less. Also, where resistant units of Bishop tuff do not occur, fewer scarps have been preserved. Bateman (1965) pointed out that large scarps are sparse in terrace deposits younger than Bishop tuff and concluded that the majority of deformation had occurred prior to the cutting of terraces along the Owens River just south of the Volcanic Tableland. Although it can be concluded that some of the faults in the Volcanic Tableland are probably Holocene-active, many of the well-defined scarps in the central and eastern parts of the Tableland are preserved because of low rates of erosion and the resistant nature of some units of the Bishop tuff, and may not necessarily delineate Holocene faulting. If zoning recommendations were to be made, it would probably be necessary to zone all well-defined faults because age distinctions cannot easily be made for individual faults.

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well defined" (Hart, 1980). Because of the complexity of the Volcanic Tableland study area and the limited amount of time available for evaluation of this area, alternative recommendations are made.

Alternative #1

Do not zone faults in the Volcanic Tableland. Time limitations for this study, the density of well-defined faults, difficulty of distinguishing the ages of these faults in Bishop tuff, and the relative remoteness and lack of developmental pressure for this area all indicate that recommendations for zoning faults for special studies should not be made at this time. However, many faults are well defined, and there is evidence suggesting that tectonic processes causing the typical Tableland pattern of faulting have continued into latest Pleistocene and Holocene time. Thus, if developmental pressures change, recommendations for zoning should be reconsidered.

Alternative #2

Zone for special studies all well-defined faults in the Volcanic Tableland study area, based on the mapping of Bateman (1965) (Rovana 7-1/2-minute quadrangle, NW 1/4 and the northwest part of the SW 1/4 of the Bishop 15-minute quadrangle) and Crowder and Sheridan (1972) (SW 1/4 White Mountain Peak 15-minute quadrangle) as shown on figures 5a, 5b, and 5c. Draw appropriately wide zone boundaries as indicated on figures 5a-5c. Do not zone faults in the SW 1/4 Casa Diablo Mountain 15-minute quadrangle.

I recommend alternative #2 as the faults meet our criteria for zoning. Also, the southern extension of the Vol. Tableland faults west of Bishop are currently subject to some development pressures.
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REFERENCES

Bailey, R.A., and Koeppen, R.P., 1977, Preliminary geologic map of Long Valley caldera, Mono County, California: U.S. Geological Survey Open File Report 77-468, scale 1:62,500.

Bateman, P.C., 1965, Geology and tungsten mineralization of the Bishop district, California: U.S. Geological Survey Professional Paper 470, Plates 2, 3, 5, and 7, scale 1:62,500.

Bryant, W.A., 1984a, Northern Owens Valley, Fish Slough, and White Mountains frontal faults, Inyo and Mono Counties: Unpublished Fault Evaluation Report FER-153.

Bryant, W.A., 1984b, Round Valley fault zone, Inyo and Mono Counties: Unpublished Fault Evaluation Report FER-158.

Crowder, D.F. and Sheridan, M.F., 1972, Geologic map of the White Mountain Peak quadrangle, Mono County, California: U.S Geological Survey Geologic Map GQ-1012, scale 1:62,500.

Hart, E.W., 1980, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42, 25 p.

Jennings, C.W., 1975, Fault map of California with locations of volcanoes, thermal springs, and thermal wells: California Division of Mines and Geology Geologic Data Map No. 1, scale 1:750,000.

Real, C.R., Toppozada, T.R., and Parke, D.L., 1978, Earthquake catalog of California, January 1, 1900-December 31, 1974 (1st edition): California Division of Mines and Geology Special Publication 52, 15 p.

Rinehart, C.D. and Ross, D.C., 1957, Geologic map of the Casa Diablo Mountain quadrangle, California: U.S. Geological Survey Map GQ-99, scale 1:62,500.

Sheridan, M.F., 1975, Tectonic displacement of the Bishop tuff: California Geology, v. 28, no. 5, p. 107-108.

Sheridan, M.F. and Crowder, D.F., 1964, Geologic map of the southwest quarter of the White Mountain Peak quadrangle, Mono County, California: U.S. Geological Survey Open File Map, scale 1:24,000.

Strand, R.G., 1967, Geologic map of California, Mariposa sheet: California Division of Mines and Geology, scale 1:250,000.

U.S. Bureau of Land Management, 1977, Aerial photographs BLM CA 01-77 1-31-11 to 24; 4-27-6 to 11, 28-7 to 20, 29-3 to 20; 5-26-6 to 11; 6-30-7 to 24, color, vertical, scale 1:24,000.

U.S. Forest Service, 1972, Aerial photographs IN04 5-19 to 23; 6-90 to 93, 6-144 to 150; 10-71 to 72, color, vertical, scale 1:15,840.

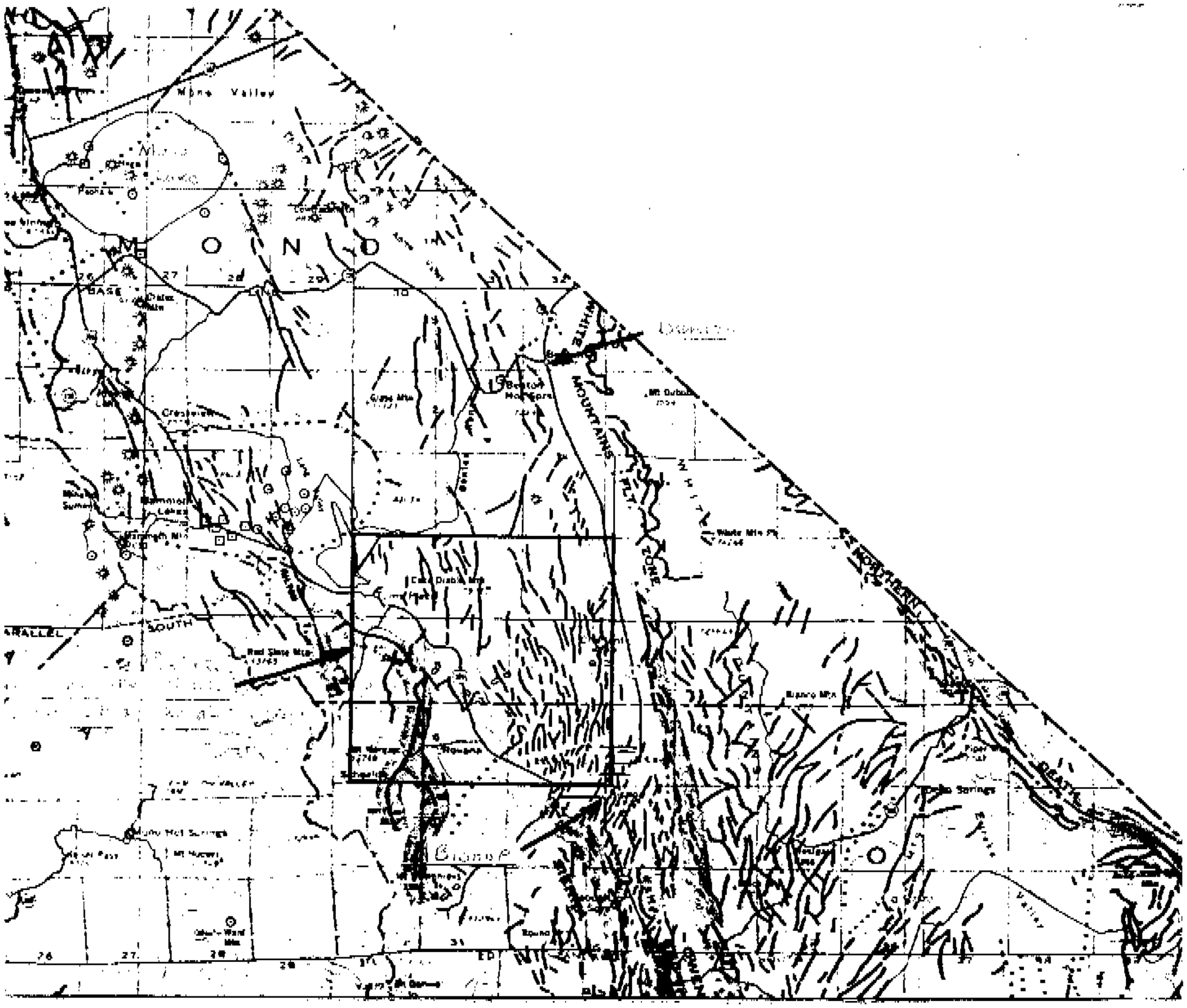

Figure 1 (to FER-162). Location of faults in the Volcanic Tableland study area. Base map from Jennings (1975), scale 1:750,000.

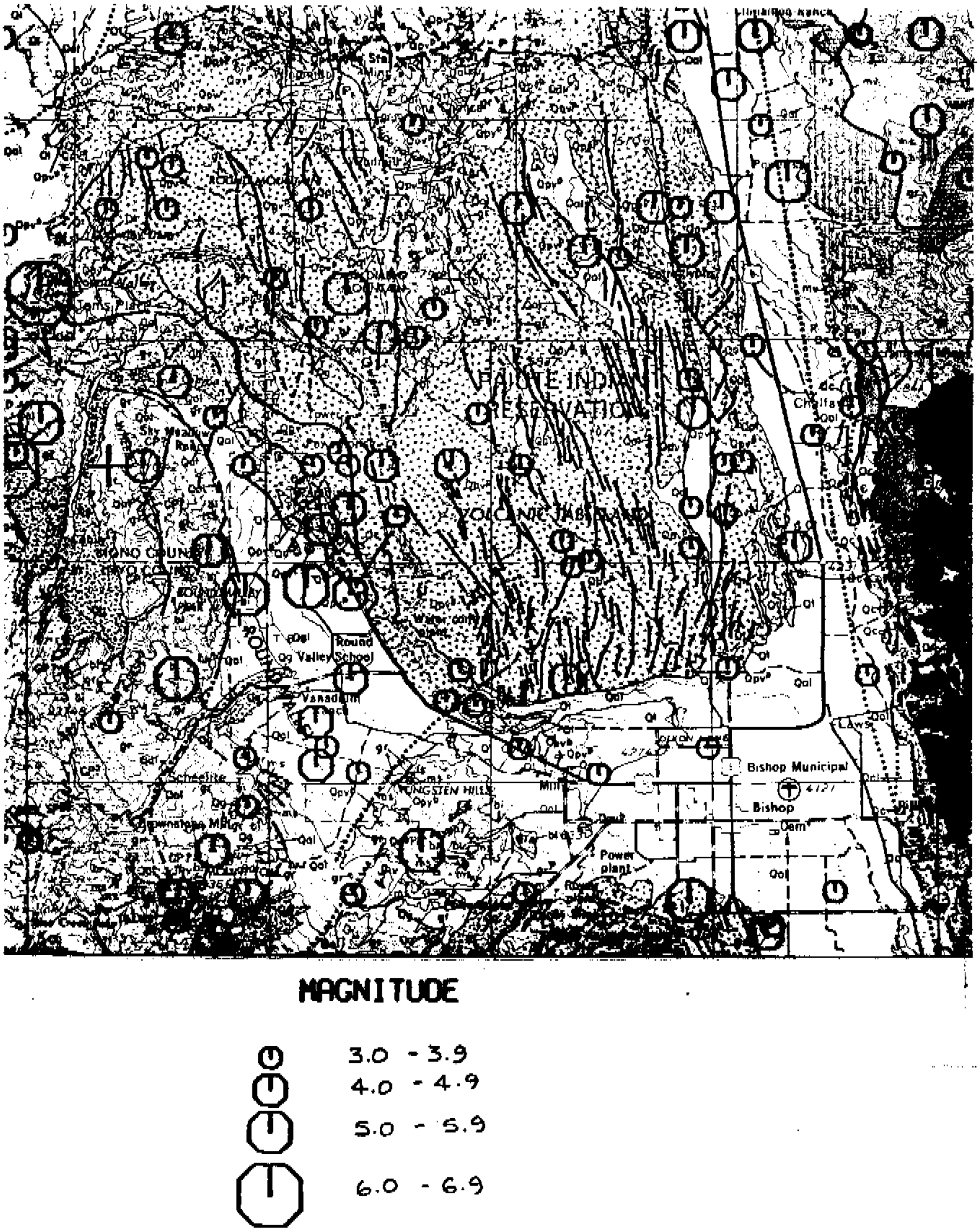

Figure 4 (to FER-162). Plot of seismicity in the Volcanic Tableland study area for the period 1900-1974. Quality of epicenter locations ranges from A to D and are mainly from CIT (Real, et al., 1978). Base map from Strand (1967), scale 1:250,000.